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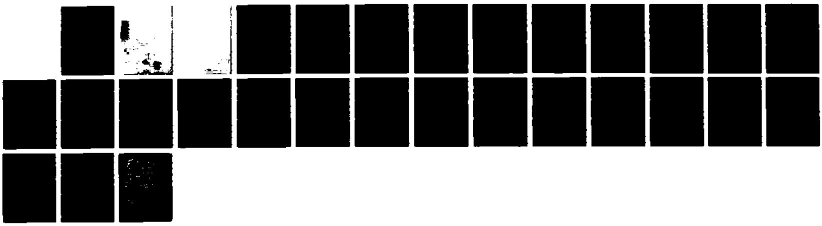

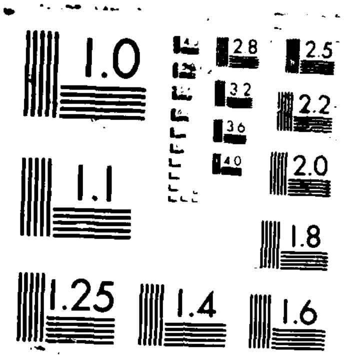
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Wearing of the M17A2 protective mask alters a soldier's ability to detect, acquire, and track moving targets. In this study we attempted to describe the decrements in pursuit tracking performance produced by the M17A2 protective mask. Sixteen male volunteers used an optical tracking device to track targets at a constant angular velocity of 5 mrad/sec under bright and dim ambient light conditions in the BLASER pursuit tracking simulator. Volunteers were assigned randomly to either a control or an experimental group. Only the experimental group wore the M17A2 protective mask during testing. The Analysis of Variance of the Percent Time-on-Target (%TOT), Root Mean Square (RMS) and Maximum Absolute Error (MAE) revealed statistically significant performance decrements for those wearing the protective mask. These effects were seen in both the vertical and horizontal axes. During the bright light trials tracking performance improved as the volunteers adjusted to the presence of the mask. Such evidence emphasizes the need for training while using the mask. Wearing the mask produced the greatest effects under low ambient light condition (e.g., %TOT < 57%). Our results

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suggest that soldiers using direct-view optics (e.g., TOW, GLLD) could experience difficulties arising from the decrease in field of view (FOV) and the inability to scan in the normal horizontal manner while wearing the M17A2 protective mask.

ABSTRACT

Wearing of the M17A2 protective mask alters a soldier's ability to detect, acquire and track moving targets. In this study we attempted to describe the decrements in pursuit tracking performance produced by the M17A2 protective mask. Sixteen male volunteers used an optical tracking device to track targets at a constant angular velocity of 5 mrad/sec under bright and dim ambient light conditions in the BLASER pursuit tracking simulator. Volunteers were assigned randomly to either a control or an experimental group. Only the experimental group wore the M17A2 protective mask during testing. The Analysis of Variance of the Percent Time-on-Target (%TOT), Root Mean Square (RMS) and Maximum Absolute Error (MAE) revealed statistically significant performance decrements for those wearing the protective mask. These effects were seen in both the vertical and horizontal axes. During the bright light trials tracking performance improved as the volunteers adjusted to the presence of the mask. Such evidence emphasizes the need for training while using the mask. Wearing the mask produced the greatest effects under low ambient light condition (e.g., %TOT < 57%). Our results suggest that soldiers using direct-view optics (e.g., TOW, GLLD) could experience difficulties arising from the decrease in field of view (FOV) and the inability to scan in the normal horizontal manner while wearing the M17A2 protective mask.

PREFACE

We would like to express our appreciation to Virginia Gildengorin, PhD, for her assistance in experimental design and statistical evaluation of the data and SP4 Ronald Klinker for his assistance in the conduct of this experiment.

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The Effects of the M17A2 Protective Mask on Human Pursuit Tracking Performance

Psychomotor skills play an important role in a soldier's effectiveness and survivability in combat. Therefore, factors that will enhance or degrade psychomotor performance are important to the U.S. Army. In the field each soldier is issued an M17A2 protective mask as his primary means of survival in a chemical warfare environment. When wearing the protective mask, changes in performance can be expected. Enhanced performance in harsh environments, which was attributed to the ocular protection afforded by the mask, was reported by Barnes et al (1). In most cases, visual degradation has been reported (2). This decrease in visual performance is associated with altered visual scanning strategies and a decreased field of view (FOV) (3). While masked, soldiers tend to scan for targets diagonally rather than by using the normal horizontal scanning strategy. It has been shown that scanning an area diagonally requires additional scanning time. This leads to increased target acquisition times and decreased target detection rates (3). Decrements in the FOV of up to 2 degrees have been observed in masked soldiers using various sights fielded by the U.S. Army. This decrease in the FOV is a function of the stand-off distance (i.e., the distance from the eye to the lens of the mask). As stand-off distance increases, the FOV decreases (1). Since the peripheral retina is sensitive to motion cues, the loss of FOV for target detection may be significant (4).

Examination of earlier work suggested that the effects of the M17A2 protective mask on many performance tasks, including tracking performance, had not been studied (5). Small-arms tests conducted while volunteers were wearing protective masks and firing the M16 rifle have shown that the mask produced a sixfold increase in the cant angle (1,2). A soldier's ability to aim his weapon is a function of the cant angle (i.e., the tilt position of the head with respect to the long axis of the rifle). The smaller the angle, the better the performance. Although these studies have shown that visual degradation was produced by the mask, no statistically significant effects have been reported. Since the firing strategies of the M16 (e.g., ambush) vs the TOW missile launcher (i.e., pursuit tracking) may be different, information obtained from small-arms tests should not be generalized to a pursuit tracking scenario.

The Division of Ocular Hazards, Letterman Army Institute of Research (LAIR), has developed a laboratory pursuit tracking simulator that has been used extensively to study biomedical factors affecting operator performance (6). The BLASER simulator allows researchers to systematically study pursuit tracking in a controlled laboratory situation. Previous work has shown that pursuit tracking performance with the BLASER simulator is comparable to tracking performance in the field using the actual weapon system (7,8).

The purpose of this study was to evaluate the effects of an M17A2 protective mask on simulator pursuit tracking performance.

METHODS

Volunteers: Sixteen male soldiers were recruited from the Letterman Army Institute of Research (LAIR). The ages of the volunteers were between 18 to 40 years. Each volunteer was briefed thoroughly on the purpose of the study and signed a Volunteer Consent/Privacy Act Statement before participating. All volunteers underwent vision screening to ensure they possessed normal visual acuity (20/20 uncorrected). Dark adaptation was also tested using the LAIR dark adaptometer. All volunteers possessed normal dark adaptation function.

Apparatus: Pursuit tracking was evaluated in the BLASER tracking simulator (8,9). The simulator consists of a scale model T-62 Warsaw Pact tank target on a terrain board and a full-sized sandbag bunker which houses a viscous-damped optical tracking device which has been shown to produce error tracking ratios similar to those of actual weapons systems (8). The optics located in the tracking device simulate a distance of 1 km. The target is track mounted and driven across the terrain in an arc located 5 m from the operator. The tank traverses either a left-to-right or a right-to-left path across the terrain for 15 sec at a constant angular velocity of 5 mrad/sec. A 0.52-mrad square aiming patch is affixed to one side of the tank in a center-of-mass position. An infrared light-emitting diode (IR LED), located in the center of the aiming patch, is imaged by a television camera mounted coaxially with the optics of the tracking device. The IR LED is invisible to the operator. Its signal provides a reference source for a microprocessor and associated software to monitor performance electronically.

Tracking performance data were collected under two ambient light conditions: bright (260 lm/m^2sr) and dim (0.35 lm/m^2sr). The dim ambient light condition approximated dawn/dusk and was created by inserting a 2.7 OD Wratten filter stack in the optical pathway of the tracking device. The BLASER simulator has been used extensively in the Division of Ocular Hazards over the past 7 years. Its design rationale has been described elsewhere (8-10).

Procedure: Each volunteer was seated in the bunker, and a brief explanation of the task was given. Each tracking session started with the tank on the left side of the terrain board. The trials were initiated by the command "READY, GO". After each trial the subject was instructed to "RELAX" until the next "READY" command. The volunteers were also given a summary statistic (percent time-on-target) after each trial. All volunteers tracked in both directions (left-to-right and right-to-left). The volunteers were in voice communication with the experimenter via a radio headphone set and were monitored visually via closed-circuit TV.

Training: Naive volunteers were trained to track a target under both ambient light conditions. All volunteers received 2 training sessions on 2 separate days with the BLASER simulator. On the first training day all volunteers received twenty-two 1-min trials, 11 under the bright ambient light condition and 11 under the dim ambient light condition. On the second training day all volunteers received thirty-two 15-sec trials (16 bright and 16 dim ambient light trials). The M17A2 protective mask was not worn by any volunteer during training.

Test Day: At the end of training, the volunteers were assigned randomly in an exhaustive sequence to two groups. Group 1 (control) did not use the M17A2 protective mask on test days. Group 2 (experimental) was required to wear the M17A2 protective mask during each of the 3 test days under both ambient light conditions. The three test days were composed of 10 trials/light condition for a total of 20 trials/day.

Test Scores, Statistical Design and Analysis: Volunteers were tested for changes (decrements or improvements) in tracking performance. A between-subjects design was used, whereby eight volunteers were tested while wearing an M17A2 protective mask and eight (the control group) were not. The raw horizontal and vertical data were used to calculate the variability in tracking error (standard deviation and root mean square) for each trial. Separate Analysis of Variance (ANOVA) tests were performed to evaluate the effects of light level, test days and mask condition on tracking performance. The Least Significant Difference (LSD) test was used to determine the specific post-hoc group difference of significant ANOVA results (11). The significance level was set at 0.05 for all comparisons.

Percent Time-on-Target (%TOT) was defined as the percent of time during the 10-sec data collection window that the operator maintained the crosshairs within the 0.52 mrad square aiming patch. RMS scores were computed from the following equation:

$$RMS = \sqrt{\frac{\Sigma (X_i)^2}{N}}$$

where: $X_i = x - x_o$

N = Sample size

x = location of the crosshairs at each sample point.

x_o = the center of the target aiming point

RMS error describes the variability in tracking error with respect to horizontal and vertical axes.

Vertical and horizontal maximum error scores were generated on-line by comparing the difference between the center of the target patch and the actual location of the crosshairs at a rate of 30 Hz for each trial. The maximum error scores were converted to absolute values for use in the ANOVA. The maximum absolute error scores reflect the largest excursion from the center of the aiming patch, without respect to direction of the excursion (lead vs lag and overshoot vs undershoot) (12).

RESULTS

Percent Time-on-Target: The ANOVA of the %TOT scores (Table 1) indicated statistically significant differences under both light conditions for groups (mask vs. no mask). Figure 1 graphically presents the %TOT group means and results of the post hoc LSD test (conditions with underlines in common indicate that the results of that comparison were not significantly different).

TABLE 1

Analysis of Variance Results for %TOT

		Mean Square	DF	Probability
Bright Light	Group	410.67	1	0.0140*
	Error	52.17	14	
	Test Day	26.27	2	0.0882
	Group x Day	8.53	2	0.4333
	Error	9.90	28	
Dim Light	Group	2691.00	1	0.0373*
	Error	508.62	14	
	Test Day	97.81	2	0.2761
	Group x Day	150.03	2	0.1454
	Error	72.56	28	

* Significant at the 0.05 level.

Root Mean Square: The results of the ANOVA for the RMS error scores are summarized in Table 2 and the group means graphically presented in Figure 2. Significant differences between groups (mask vs. nomask) for the vertical axis under the bright light and for the horizontal axis under the dim light were found. A significant group by test day interaction was also observed for the horizontal axis under the dim light. In Figure 2 this interaction is visually demonstrated by the significantly elevated scores on Day 2 of the mask condition. Under the bright light condition the same comparison narrowly missed achieving significance (i.e., 0.06).

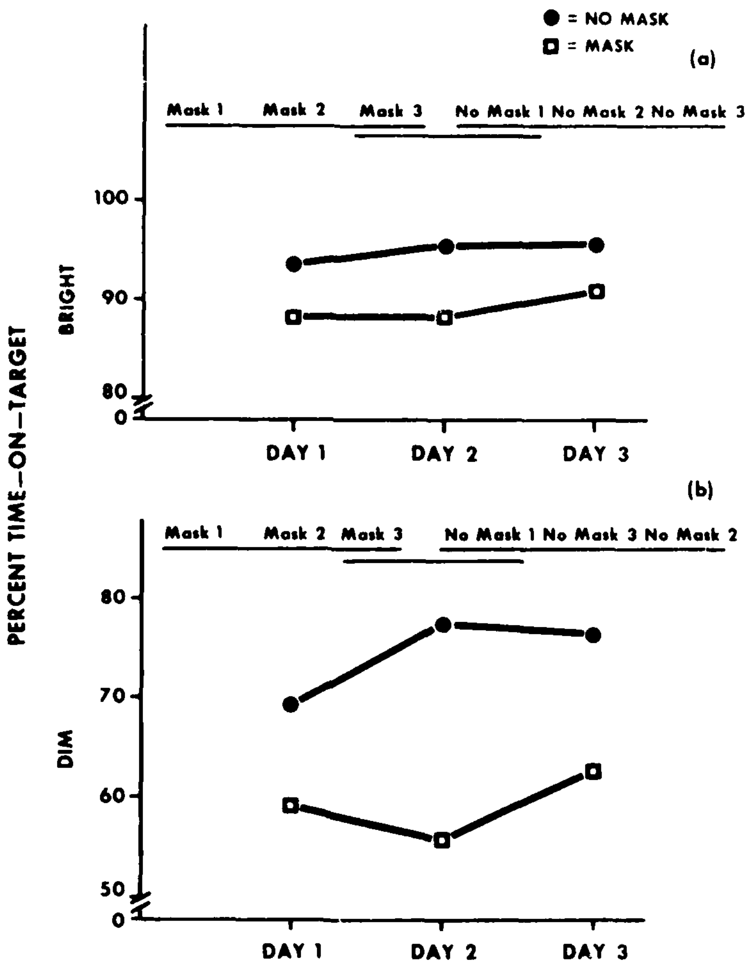

Figure 1. Percent Time-on-Target.
a) Bright Ambient Light Condition.
b) Dim Ambient Light Condition.

TABLE 2

Analysis of Variance Results on the Vertical and Horizontal RMS Error Scores.

Vertical Axis		Mean Square	DF	Probability
Bright Light	Group	0.00263	1	0.0105*
	Error	0.00030	14	
	Test Day	0.00002	2	0.8678
	Group x Day	0.00005	2	0.7399
	Error	0.00017	28	
Dim Light	Group	0.01650	1	0.1424
	Error	0.00683	14	
	Test Day	0.00147	2	0.3096
	Group x Day	0.00121	2	0.3761
	Error	0.00120	28	
Horizontal Axis				
Bright Light	Group	0.00373	1	0.4451
	Error	0.00604	14	
	Test Day	0.00083	2	0.2782
	Group x Day	0.00187	2	0.0657
	Error	0.00062	28	
Dim Light	Group	0.02847	1	0.0471*
	Error	0.00601	14	
	Test Day	0.00263	2	0.1236
	Group x Day	0.00568	2	0.0154*
	Error	0.00117	28	

* Significant at the 0.05 level.

Figure 2
a & b

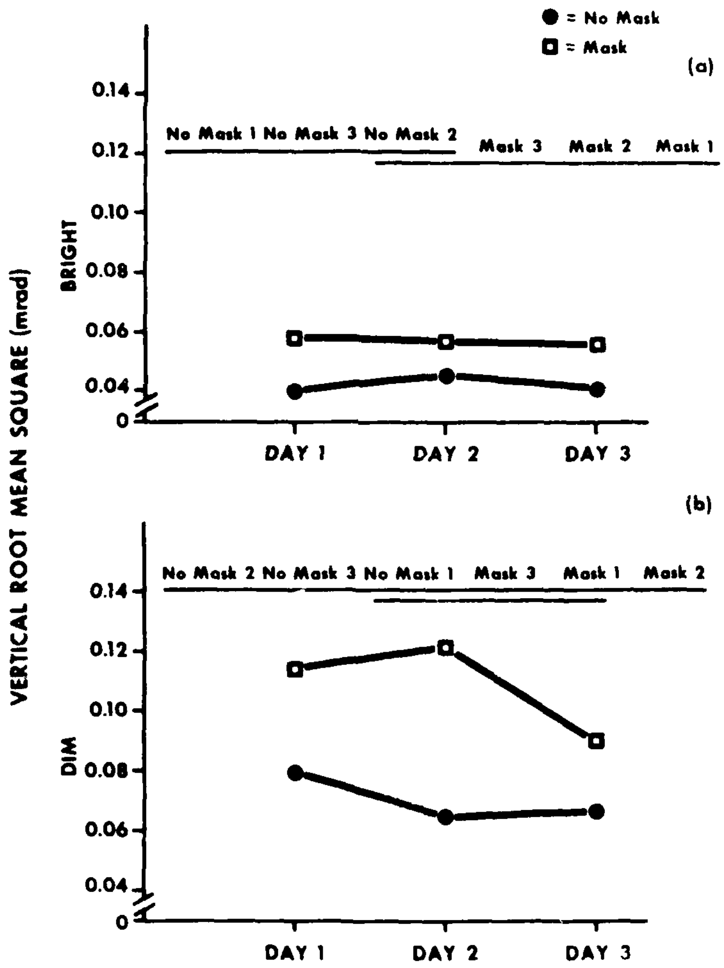

Figure 2. Vertical Root Mean Square.
a) Bright Ambient Light Condition.
b) Dim Ambient Light Condition.

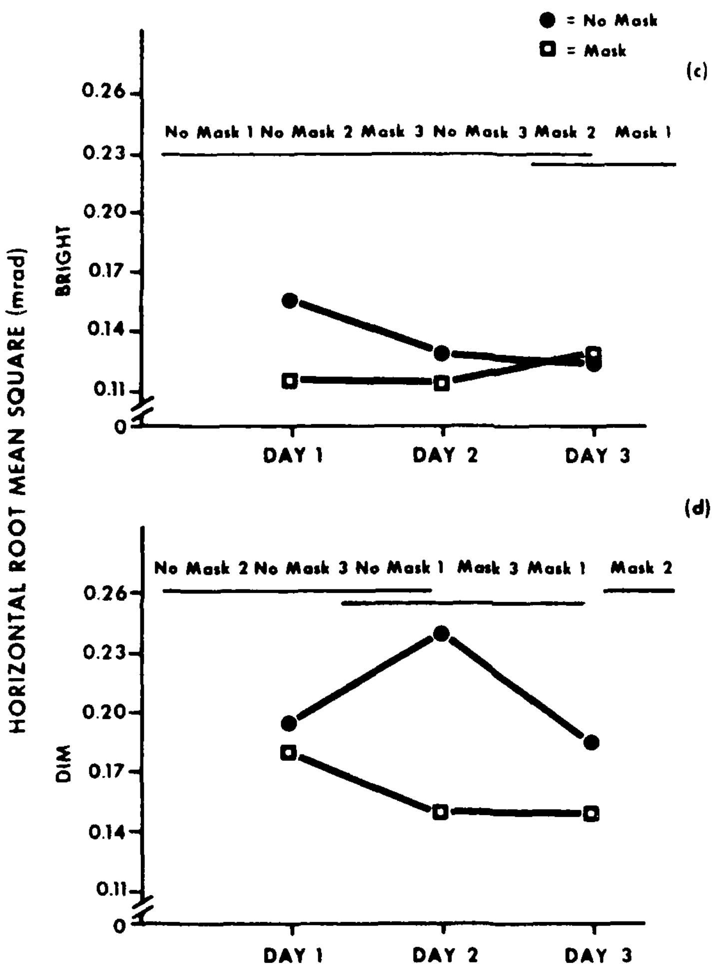

Figure 2. Horizontal Root Mean Square.
c) Bright Ambient Light Condition.
d) Dim Ambient Light Condition.

Maximum Absolute Error: The ANOVA results (Table 3) of the vertical maximum absolute error scores indicated a significant effect for group under the bright condition. However, under the dim light trials, while this comparison narrowly missed achieving significance ($p= 0.08$), the result was determined to be not significant at the 0.05 level. These results can be seen in Figure 3 where in each case the MAE score for the mask condition is always higher, but the difference for the dim light trials was not quite as large.

For the horizontal axis ANOVA the group and the group X day interaction comparisons were significant under both bright and dim ambient light conditions. The significant interaction was likely due to the significantly higher scores for the mask condition of Day 1 for the bright light trials and for the mask scores on Day 2 during the dim light trials.

TABLE 3

Analysis of Variance Results on the Vertical and Horizontal MAE Scores.

Vertical Axis		Mean Square	DF	Probability
Bright Light	Group	0.00484	1	0.0217*
	Error	0.00073	14	
	Test Day	0.00053	2	0.1634
	Group x Day	0.00006	2	0.8138
	Error	0.00027	28	
Dim Light	Group	0.11920	1	0.0807
	Error	0.03364	14	
	Test Day	0.00821	2	0.2575
	Group x Day	0.00747	2	0.2893
	Error	0.00576	28	
Horizontal Axis				
Bright Light	Group	0.05556	1	0.0534*
	Error	0.01249	14	
	Test Day	0.00527	2	0.1463
	Group x Day	0.01018	2	0.0301*
	Error	0.00256	28	
Dim Light	Group	0.17448	1	0.0361*
	Error	0.03248	14	
	Test Day	0.00362	2	0.6071
	Group x Day	0.03904	2	0.0098*
	Error	0.00713	28	

* Significant at the 0.05 level.

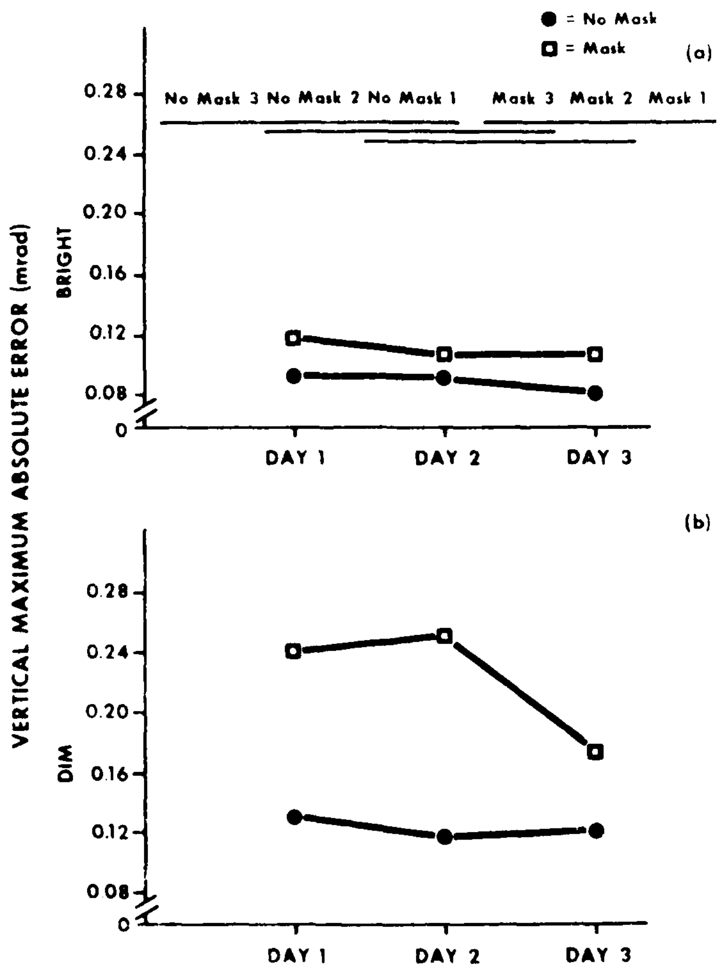

Figure 3. Vertical Maximum Absculte Error.
a) Bright Ambient Light Condition.
b) Dim Ambient Light Condition.

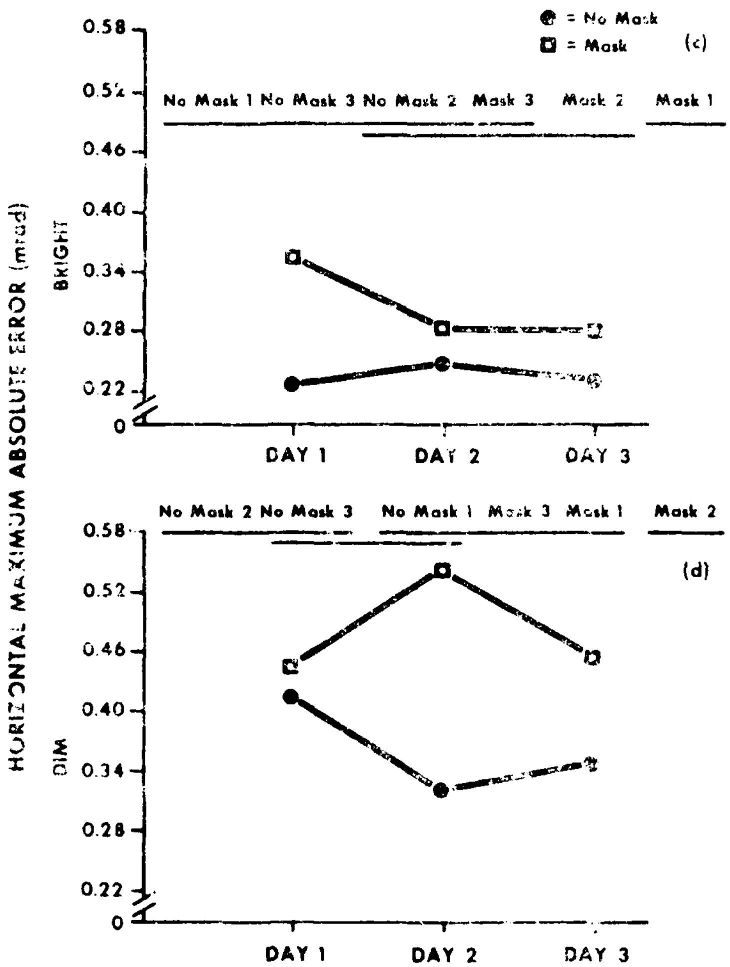

Figure 3. Horizontal Maximum Absolute Error.
c) Bright Ambient Light Condition.
d) Dim Ambient Light Condition

DISCUSSION

Performance of militarily relevant tasks (i.e., M16 rifle firing) has been shown to deteriorate when soldiers wore M17A2 protective masks (2). This has been attributed to changes in vision due to alterations in field of view (FOV), target discriminability, cant angle and scanning strategies (1,3,13).

In this study we examined the effects of the M17A2 protective mask on pursuit tracking performance. We found that tracking performance decreased when the mask was worn. Percent time-on-target scores decreased by an average of 7.8% in the bright light condition and 21.0% in the dim light condition (Figure 1). For the %TOT scores the groups remained significantly different and did not change significantly across days.

The tracking error as measured by changes in RMS data showed significant increases in both the vertical and horizontal axes (except for the dim vertical data) when the mask was compared with the no mask trials. For the horizontal RMS dim light trials the additional practice afforded by the 3 test days did not significantly improve these RMS scores. However, for the bright light trials horizontal RMS scores had improved by Day 3, and the masked trials were not significantly different than the no mask trials. On the horizontal axis the scores remained essentially unchanged across the three days, and the RMS mask trial scores were significantly higher than those of the no mask trials.

The ANOVA results of the MAE error scores were similar to those of the RMS ANOVA where significant group effects were noted for all but the dim vertical comparison. Further, a significant improvement in horizontal MAE scores was noted when Day 1 scores were compared with Day 3 scores under the bright light condition. Under the dim light masked condition the MAE scores essentially remained unchanged, and were significantly higher than the no mask group.

In earlier reports this tracking task has been shown to contain a strong horizontal component. Similar findings were also expected for this study. However, significant effects for the vertical axis were seen in two of the four comparisons for RMS and MAE.

During this experiment several volunteers noted a change in head position with regard to the ocular of the tracking device. This change in head position was an increase in cant angle and is seen as the major factor contributing to the significant increase in the vertical error scores. It was repeatedly observed that the operator was forced to reposition his head in relation to the tracking device several times during the 15-sec presentation of the target. During this repositioning large excursions from the target, which were reflected in the significantly increased MAE scores for the masked group, occurred.

The distance of the operator's eye from the eyepiece of the designator (approximately 2 cm) caused a greater than 1 degree loss in the FOV. This loss of FOV was in the periphery of the operator's visual field and was not viewed as a significant factor while the operator was on target since the crosshairs of the reticle are located in the center of the visual field. However, when the operator went off target, the loss of the FOV severely hampered target reacquisition. Further, since the peripheral retina is sensitive to motion cues and is essential to visual signal detection (4,13), this reduction in the FOV would be expected to increase target reacquisition times.

The act of simply wearing the mask may have had an effect on tracking performance. Volunteers reported that the constricting nature of the mask made it difficult to concentrate on the tracking task. Some volunteers reported that some of their excursions from the target were caused by the tendency of the mask's face-piece to bulge out when they exhaled. Others reported that the smell and the [illegible] of the mask were distracting. These problems seemed [illegible] overcome by Day 3. During bright light trials a significant training effect was observed over the course of this study (Figures 2c and 3c). During the bright light trials tracking performance improved as the volunteers adjusted to the presence of the mask. Such evidence emphasizes the need for training while using the mask.

CONCLUSION

We have studied the effect of the M17A2 protective mask on pursuit tracking performance. Our results suggest that soldiers using direct-view optics (e.g., TOW, GLLD) would experience severe difficulties in performance of their mission if they were forced to operate in a chemical warfare environment. These difficulties could arise from the decrease in the FOV and the inability to visually scan the scene in the normal horizontal manner. Training operators of such devices with the M17A2 protective mask would provide tracking strategies beneficial to the operator. Without this training the success of the mission could be compromised.

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